OPTICAL NAVIGATION SIMULATION AND PERFORMANCE ANALYSIS FOR OSIRIS-REX PROXIMITY OPERATIONS

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Optical Navigation Concept of Operations

The OSIRIS-REx mission timeline with OpNav milestones is presented in Figure 1. The first three proximity operations (ProxOps) mission phases focus on Navigation. During these phases, OSIRIS-REx approaches Bennu, conducts equatorial and polar flybys in Preliminary Survey, and inserts into the first mission orbit: Orbit A. During these phases, the OpNav techniques evolve from point-source to resolved-body centroiding to landmark tracking.

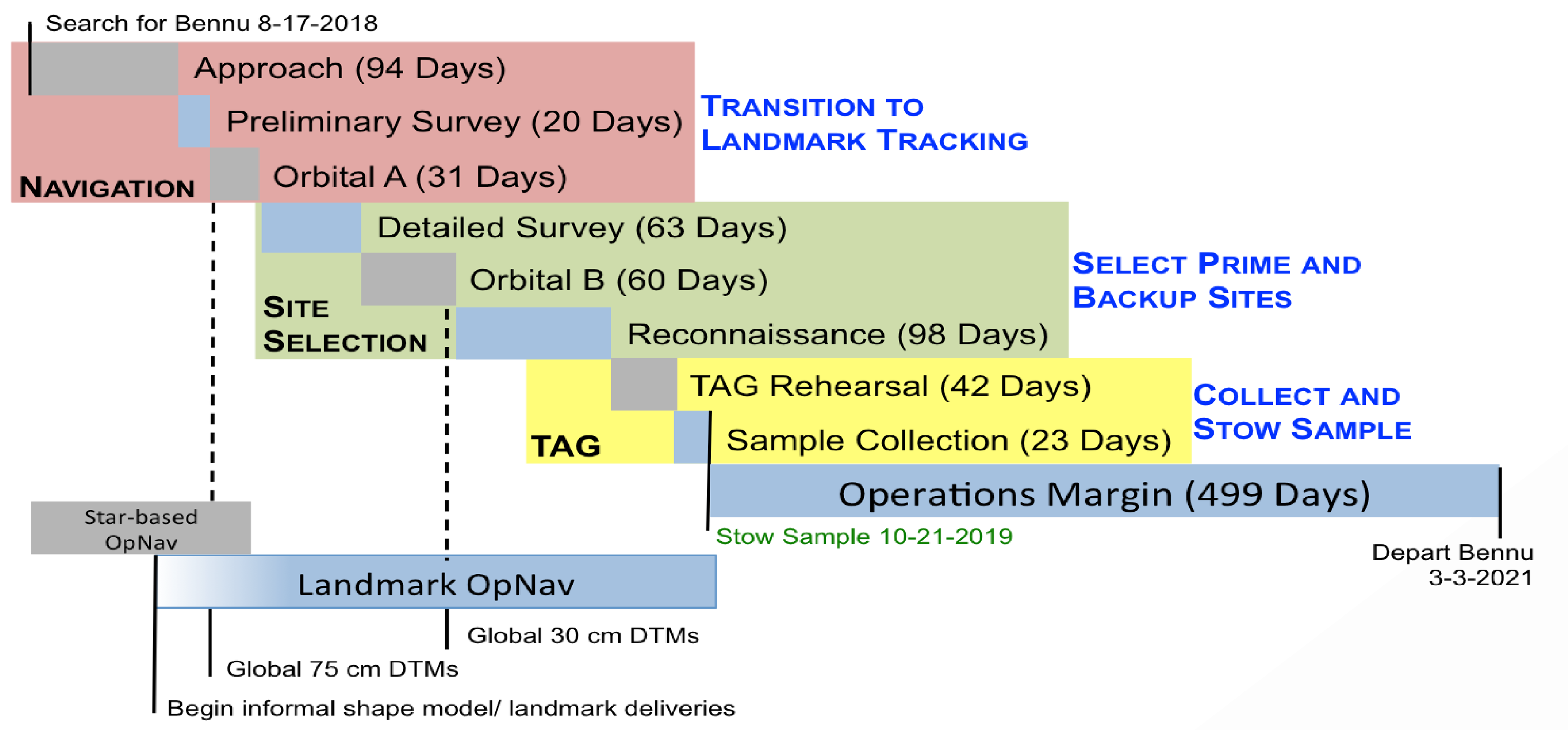

Figure 1. The OSIRIS-REx mission timeline with OpNav milestones

OpNav utilizes five OSIRIS-REx imagers during different mission phases: PolyCam (0.8° FOV), MapCam (4° FOV), and SamCam (20.8° FOV) are part of the OCAMS suite and NavCam1 and NavCam2 (33°x44° FOV) make up part of the TAGCAMS suite. Table 1 shows the OpNav imaging plan by mission phase. Navigation Training Exercises 1 & 2 cover part of Approach, and the Orbit A insertion, which both use the star-based OpNav image processing software suite, KXIMP. A high level KXIMP image processing flow is described in Figure 2. A variety of algorithms and modeling parameters are selectable for the body centroid calculation.

Table 1. OpNav Imaging Plan by Mission Phase. *Denotes sequences w/ alternating long and short exposures.

	Pre Approach	Approach			Prelim Survey	Orbit-A	Detailed Survey	Orbit-B	Recon	TAG rehearsal	Sample Collection
		Before AAM1	Before AAM3	After AAM3							
Imaging Frequency	-	1 set/3 days	1 set/day	1 set/day	8 sets/day	8 sets/day	12/day	12/day	12/day	12/day	12/day
# images/set	-	8	16*	16*	4*	4*	2	2	2	2	2
PolyCam	Cal	PRIME	PRIME	-	-	-	-	-	-	-	-
MapCam	Cal	BU1	BU1	PRIME	-	-	-	-	-	-	-
SamCam	Cal	-	-	-	BU2	BU2	BU2	BU2	BU2	BU2	BU2
NavCam1	Cal	-	-	BU1	PRIME	PRIME	PRIME	PRIME	PRIME	PRIME	PRIME
NavCam2	Cal	-	-	BU2	BU1	BU1	BU1	BU1	BU1	BU1	BU1

NTE1 NTE2

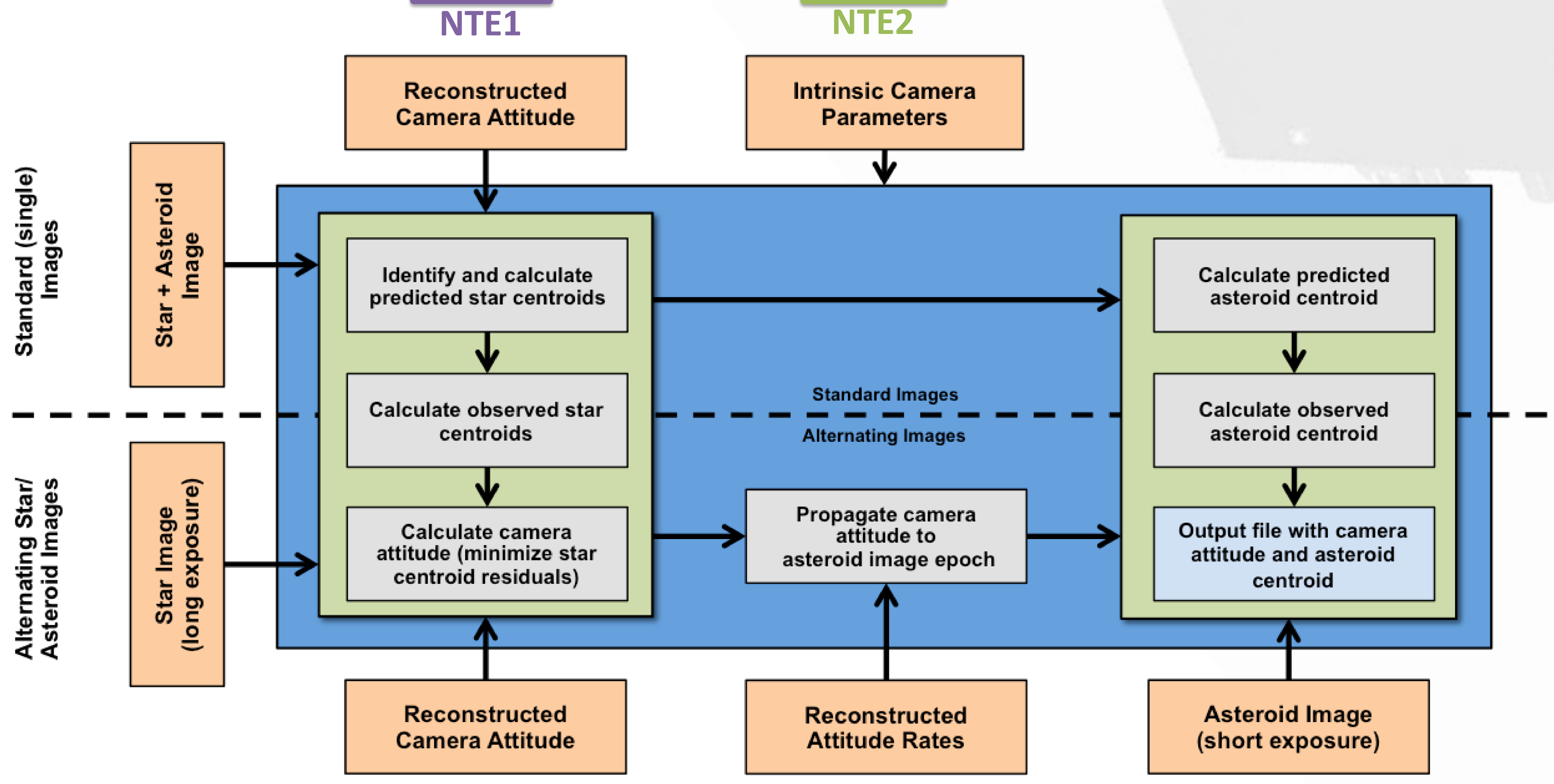

Figure 2. KXIMP Star-Based OpNav Software Processing Flow

Navigation Training Exercise 1 (NTE1) Overview

A primary goal of NTE1 was to exercise the team's ability to process star based OpNav data as Bennu grows from an unresolved to a resolved object and incorporate this data with radiometric Range, Doppler, and DDOR. Figure 3 shows NTE1 spanning AAM-2 - 1 day through AAM-2a + 2 days, allowing for an AAM-2 and AAM-2a reconstruction as well as AAM-2a and AAM-3 maneuver design and verification activities.

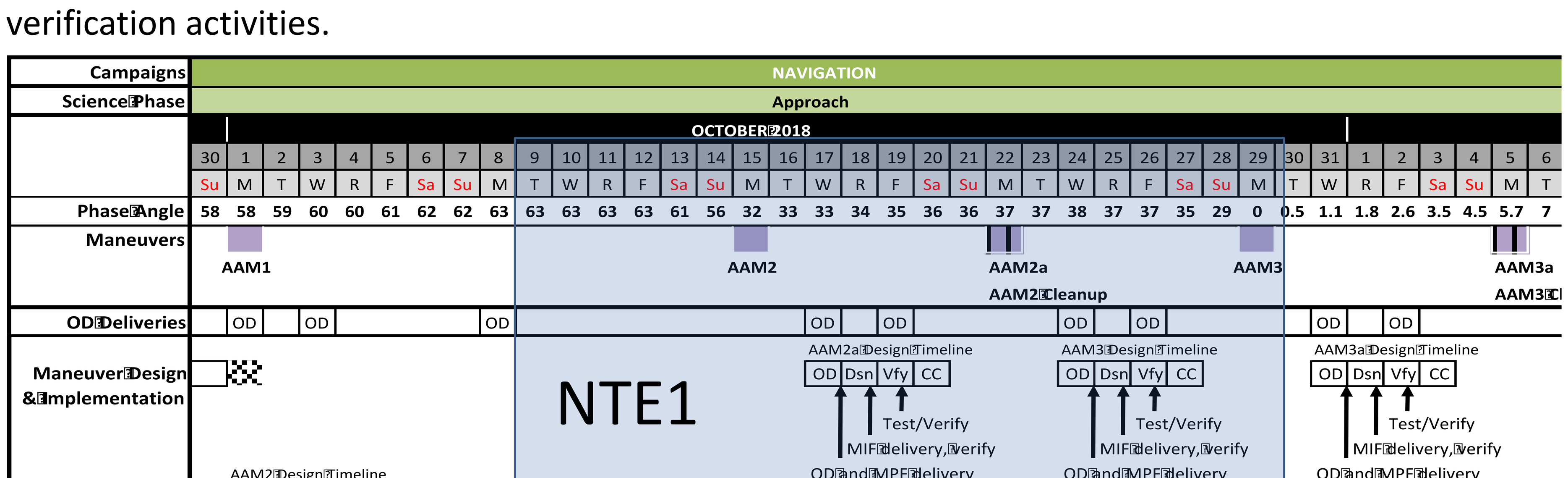

Figure 3. NTE1 Test Simulation Timeline

Navigation Training Exercise 2 (NTE2) Overview

NTE2 was designed to test the FDS team's ability to insert into the first orbit around Bennu. The test spanned maneuver M7P through M5A, which covers the 7-km south pole flyby, the drift away from and re-approach to the asteroid, and the Orbit-A insertion. Similar to NTE1, the navigation team used radiometric Range, Doppler, and DDOR as well as star-based optical navigation of a resolved object as the measurement types.

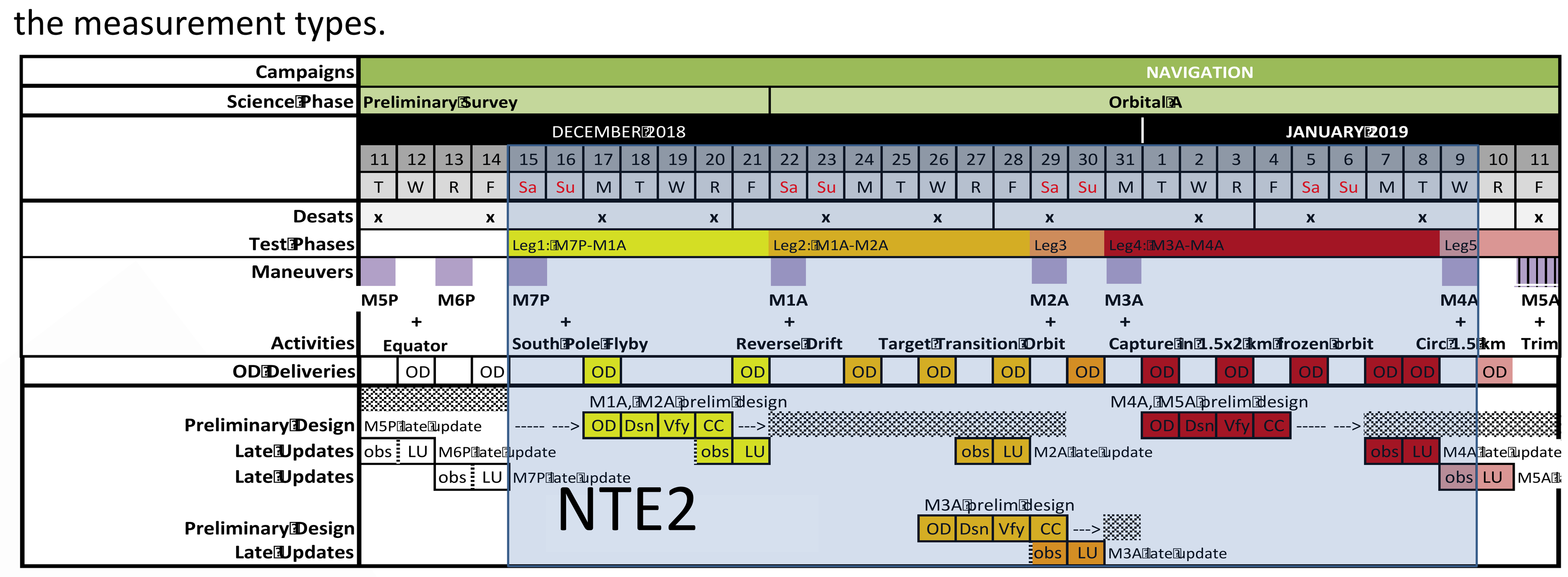

Figure 4. NTE2 Test Simulation Timeline

OpNav Image Processing Techniques

The NTE1 and NTE2 images were simulated as long + short exposure pairs, mimicking flight ConOps. The long exposures are used to image background stars and solve for the inertial camera attitude, while the short exposures are used to calculate the centroid of Bennu. Figure 5 shows KXIMP post-processing centroid results, with shape model overlay.

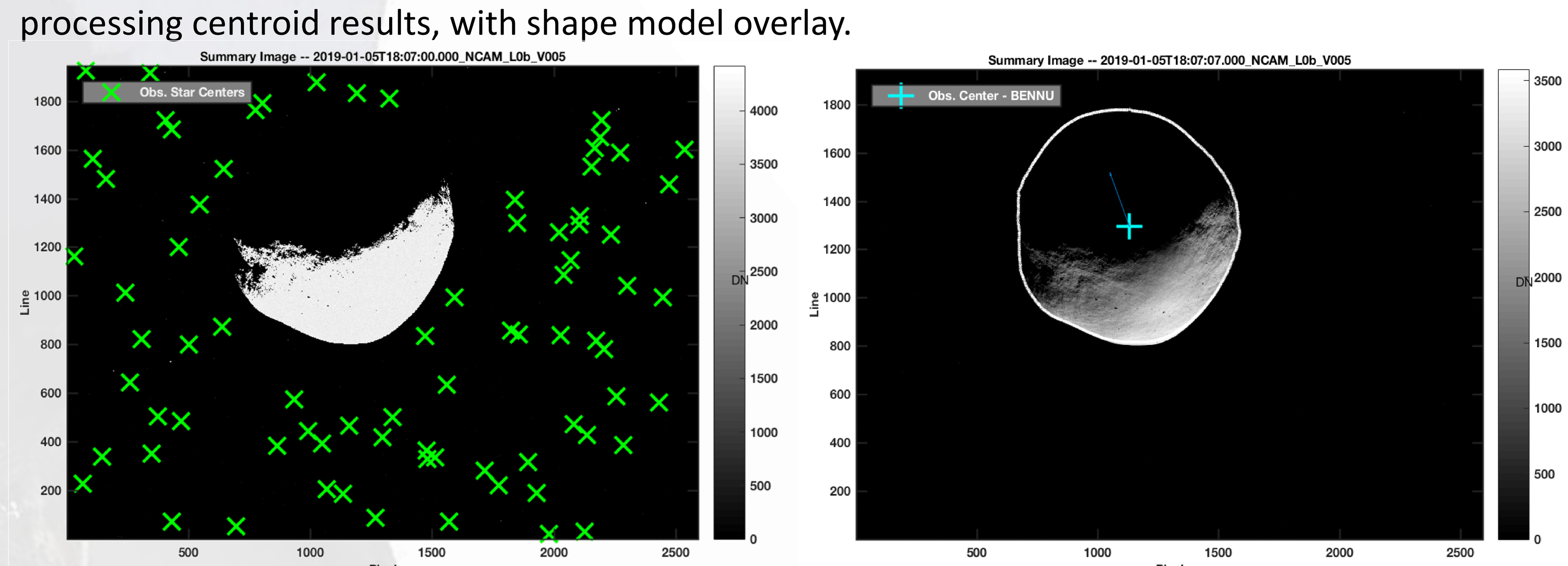

Figure 5. Post-processed long/short exposure pair, showing observed star and body centroids

OpNav Image Processing Results

Plots of the NTE2 Bennu centroid residuals computed with respect to orbit determination solution OD012 are shown in Figure 6. A perturbation to the pole position and spin rate cause small errors in the solution. Figure 7 shows both NTE1 and NTE2 centroid residuals plotted with respect to truth. In addition to pole perturbation errors, there is a -0.7 px bias in the Bennu limb direction in NTE2 images that has not yet been explained. Still, the results are well within expected and required performance.

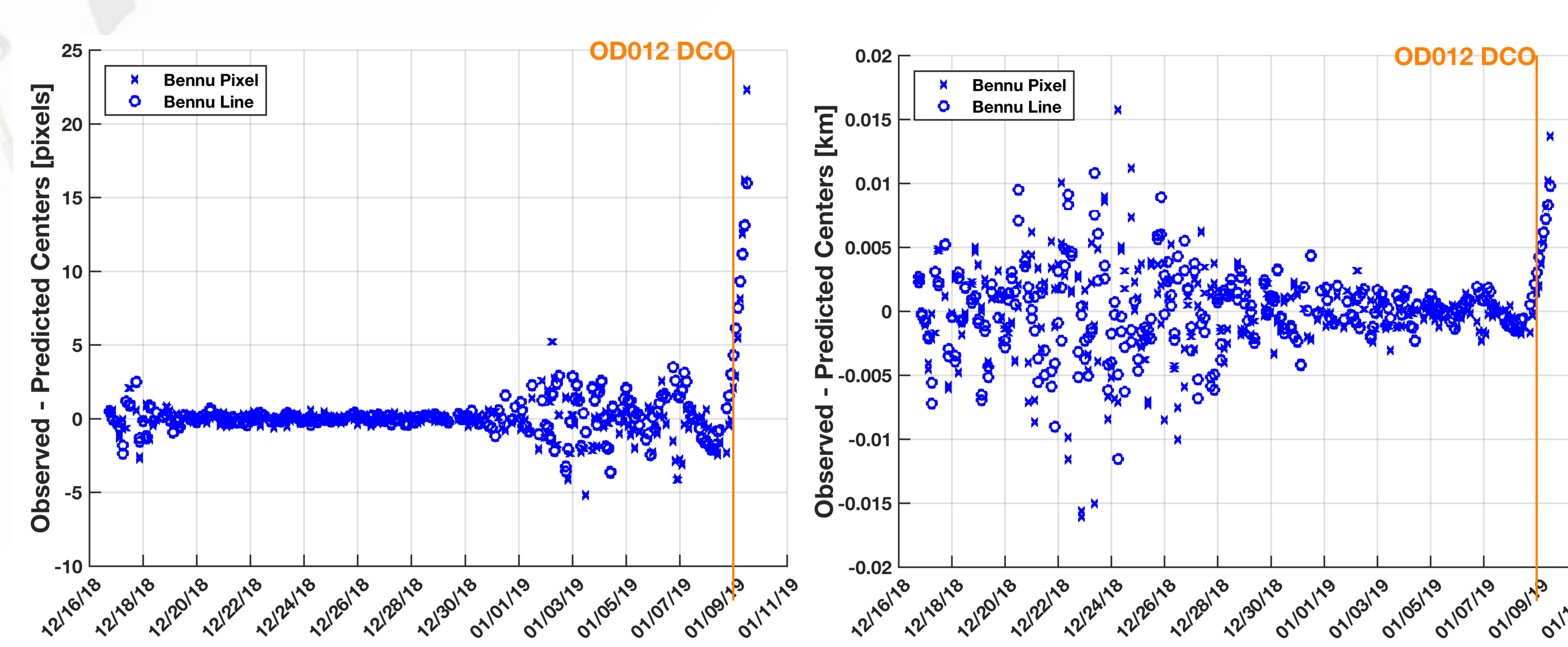

Figure 6. NTE2 centroid residuals w.r.t. OD012 trajectory, plotted in pixel and kilometer space

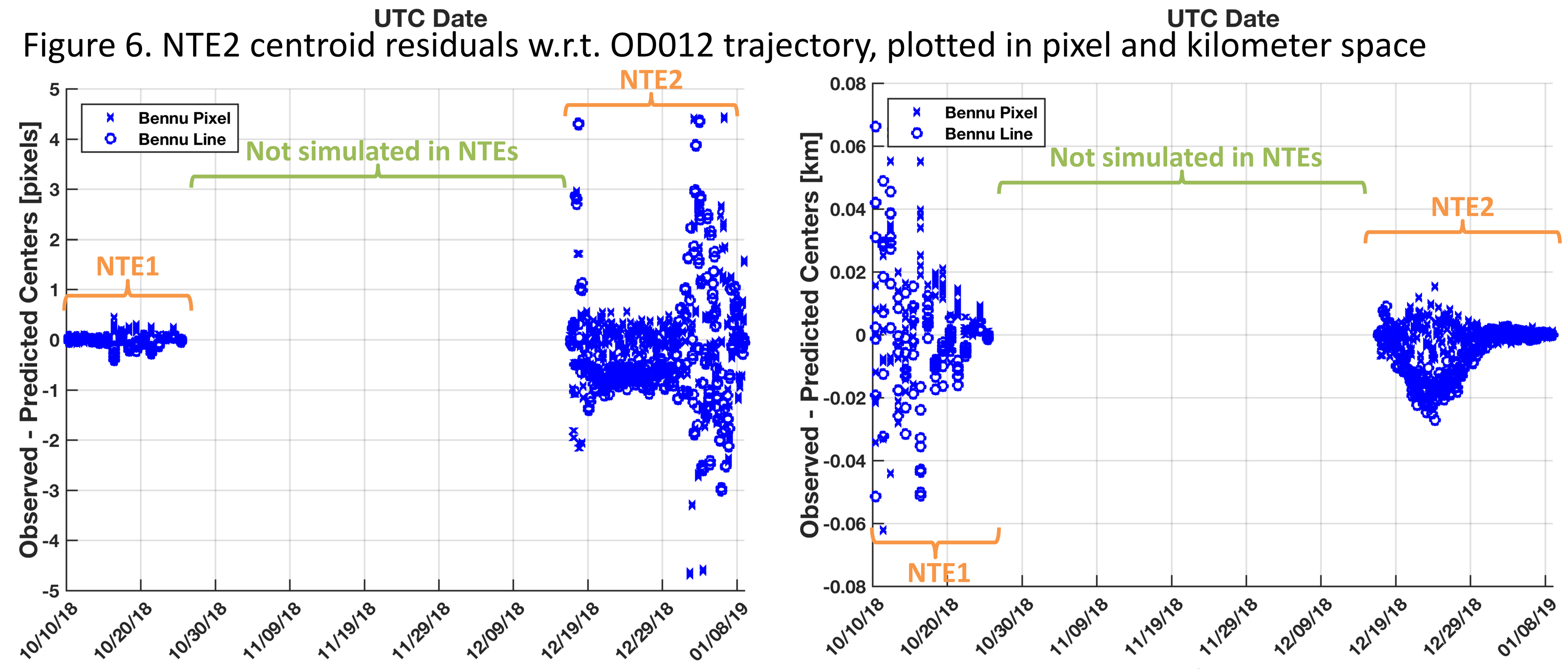

Figure 7. NTE1 and NTE2 centroid residuals w.r.t. truth centers, plotted in pixel and kilometer space